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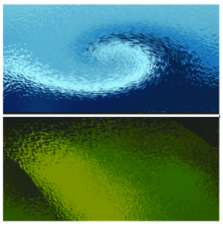

EDITORIAL

Coastal lagoons of Southern Europe: recent changes and future scenarios

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Abstract

1 - As a consequence of their location between land and open sea, coastal lagoons are subject to strong anthropogenic pressures due to tourism and/or heavy shellfish/fish farming. Furthermore, they receive fresh water from their catchment areas loaded with urban, agricultural and/or industrial effluents and domestic sewages.

2 - These pressures are responsible for important ecosystem alterations i.e. eutrophication, bacterial contamination, algal blooms (toxic or not), anoxia and fish kills. Further, additional problems arise from costal erosion, subsidence and effects related to extreme meteorological events, typical from Mediterranean areas.

3 - The development of management tools for coastal lagoons is a complex task requiring interdisciplinary research and active interaction with the end-users. By developing and implementing a set of information tools (Environmental databases, GIS, watershed and lagoon hydrodynamic coupled with biological models), the DITTY project aimed at the development of the scientific and operational bases for a sustained and rational utilisation of the available resources in Southern European lagoons in five case studies: Ria Formosa (Portugal), Mar Menor (Spain), Thau Lagoon (France), Sacca di Goro (Italy) and gulf of Gera (Greece).

4 - During this project, a set of scenarios was defined with end-users and stakeholders, addressing issues such as population growth, change in land use or resource exploitation, dredging operations and water reuse. whenever appropriate. Effect of climate change is also considered, taking 2015 as time horizon.

Keywords: lagoon, watershed, modelling, biogeochemistry, nutrient, bacterial contamination, shellfish farming, eutrophication

Introduction

Coastal lagoons: definition, processes and pressures

Coastal lagoons are shallow aquatic environments located in the transitional zone between terrestrial and marine ecosystems, which span from freshwater to hypersaline conditions depending on the water balance (Kjerfve, 1994).

Several studies on coastal lagoons were published focusing on their hydrology, biology and ecological classification criteria (Battaglia, 1959; Barnes, 1980; Lasserre & Postma, 1982; Guelorget and Perthuisot, 1983; Bellan, 1987; Carrada & Fresi, 1988), whilst in the last decade emphasis was posed on functional ecology and biogeochemistry, with respect of ecosystem alterations and buffering capacity (Caumette *et al*., 1996; Schramm and Nienhuis, 1996; de Wit *et al*., 2001; Viaroli; 2003; Giordani *et al*., 2005; Viaroli *et al*., 2005).

The formation, persistence and ecosystem processes in coastal lagoons are controlled by interactions among stressors and fluxes of material between land, ocean and atmosphere which induce highly dynamics and changeable conditions (Barnes, 1980; Kjerfve, 1994). Natural threats that have the largest impact on coastal lagoons were accelerated in the last decades by subsidence and sea eustatism, as well as by changes in the regime of precipitation, river runoff and storminess (Crossland *et al*., 2005; Eisenreich, 2005). Due to the hydro-geomorphological conditions, coastal lagoons are recognised as highly unpredictable environments (de Wit *et al*., 2001). There is evidence that within certain thresholds, lagoonal communities and ecosystems are resilient to environmental changes and can buffer against external stresses. However, resilience and buffering capacities do not follow linear behaviour, but rather undergo sudden responses which can result in rapid regime shifts (Scheffer *et al*., 2001) with an irreversible displacement of pivotal community components (Valiela *et al*., 2000; Schramm, 1999).

Coastal lagoons have a great relevance as high productive ecosystem, supporting a rich specific biodiversity. Moreover, they act as spawning grounds for marine fish and invertebrates, and behave as resting areas for many species of migratory birds.

Coastal lagoons have also a human and historical dimension, since they have long been exploited for settlements and for their natural resources, especially for fishing and aquaculture which are common activities in such areas. Lagoons are also under strong anthropogenic pressures from watersheds, as they receive freshwater input, rich in organic and mineral nutrients drained from heavily exploited catchments and by the surrounding urban and industrial settlements (see for example the Venice lagoon). In the last few years, coastal lagoons have undergone an increasing tourism pressure, which contributes to further land reclamation and water demand, with an increased deterioration of water quality. In many cases, maritime (port use and management), aquaculture and fishing activities induce internal perturbations such as pollution, sediment dredging, removal of indigenous species, or change in food web structure.

The sustainability of coastal and transitional waters largely depends upon organic matter and nutrient fluxes, which in turn stimulate eutrophication processes and induce oxygen deficit especially in the bottom water mass (Cadée *et al*., 2001; Cloern, 2001; Crossland *et al*., 2005). Eutrophication is also associated with a loss of diversity in both benthic and planktonic communities, as manifested by nuisance algal blooms in many estuaries and coastal seas (Schramm and Nienhuis, 1996; Valiela *et al*., 2000). Among stressors, nitrogen rather than phosphorus loadings have increased over time (Vitousek *et al*., 1997; Howarth and Marino, 2006). Historical data indicate that nitrate fluxes and concentrations in the large rivers of the world are correlated with agriculture development and human population densities in watersheds (Cole *et al*. 1993; Valiela *et al*., 2000). Over the past 15 to 30 years, number and performances of wastewater treatment plants have increased and organic loadings to coastal waters have consequently decreased in some areas of Europe (EEA, 2003). Nevertheless, eutrophication phenomena are still persisting world-wide in coastal aquatic ecosystems, not only due to external loadings but also to internal perturbations and feedbacks (Howarth and Marino, 2006).

Global processes are now combined with local stressors. Scientific consensus is that climate change would have a pervasive influence on the future demand, supply and quality of fresh water resources in the Mediterranean region, and would add pressure to water and aquatic ecosystems in coastal areas and, specially, in coastal lagoons (Eisenreich, 2005). Because of their shallow waters and low volume compared to the adjacent sea, coastal lagoons are more subjected to be affected by global changes and external drivers such as temperature, precipitation and related river runoff, storminess and UV radiations. The IPCC (2001) report foresees in the Mediterranean area an annual temperature increase at a rate of between 0.2 and 0.6 °C per decade, an increase of short and intense precipitations, more contrast in precipitation, with an increase up to 4% in winter and a decrease of up to 5% in summer.

Coastal lagoons are common along the Atlantic and Mediterranean coasts of Southern Europe, as well as in deltaic areas of the Black Sea and along the south-eastern Baltic coast. In the current European regulation, coastal lagoons are classified as transitional waters and fall under the European Water Framework Directive (WFD; 2000/60/EC). The considerable effort to deal with WFD objectives, namely to prevent further deterioration and to enhance the status of aquatic ecosystems and water resources, requires specific measures for achieving a progressive reduction of pressures and to reinforce conservation strategies. However, due to their hydrology and geomorphology as well as to a wide array of climatic conditions, coastal lagoons present an high degree of both inter- and intra-system variability, which often bias the identification of the major variation sources of the WFD descriptors (Basset *et al*., 2006). In other words, the WFD poses the need both to develop more effective typological schemes and to identify new tools for studying and managing transitional waters. The final objective is to achieve a 'good ecological quality status' of aquatic ecosystems within 2015, which further tackles with both scientific and socio-economic issues, as well as, with the implementation and standardisation of suitable tools in support to policy and decision makers.

Brief presentation of the DITTY project and objectives

The DITTY project aimed at developing a scientific and operational bases for a sustained and rational utilisation of the available resources in Southern European lagoons, taking into account all relevant impacts from agriculture, urban and economic activities that affect aquatic environments (www.dittyproject.org). The project addressed a considerable effort on development, validation and benchmarking of models of watersheds and lagoons. Furthermore, the project emphasised the integration of scientific tools with the socio-economic assessment of management options, through a close participation of economists and stakeholders. These goals have been achieved with the implementation of a Decision Support System (DSS) prototype, which contains database, geographical information system (GIS) and mathematical models (coupled river-basin-coastal lagoon). The DSS is meant to allow simulating different scenarios and to help policy and decision makers for assessing the effectiveness of measures designed to achieve good quality status of waters and a sustainable use of resources, as described in the WFD.

The spatial framework has been designed in order to include local and specific issues in either a broader national or regional context. The DITTY project was thus performed in five costal lagoons in the Southern European Arc (Table 1, Fig. 1). These sites with their associated coastal zones are economically very important, due to fishery, aquaculture and tourism and exhibit a wide range of both natural conditions and anthropogenic pressures in the watershed (agriculture, industry and tourism).

Scenario definition – type of scenario adopted in DITTY

Scenarios are descriptions of possible futures that reflect different perspectives on the past, the present, and the future (van Notten and Rotmans 2001). They may be applied in a variety of domains such as management, economics, environmental and policy sciences. For an extensive revue of recent scenario analysis see van Notten *et al*. (2003). In the present study, we used scenarios as a coherent, internally consistent and plausible description of a future state of the system under investigation (Parry and Carter, 1998). The rationale behind is to develop or study different sets of assumptions and consequences in order to avoid unsustainable development and future crisis. A scenario contains qualitative information with varying amounts of quantitative data depending on our present knowledge of the system and our ability to forecast actual trends in the future. In that sense, the scenarios developed in the DITTY project can be categorised as decision-support, forecasting, formal (quantitative) scenarios, according to the typology described by van

Table 1. Main characteristics of the five lagoons considered in the DITTY project. TR: tidal regime, M: macrotidal, m: microtidal, n: non tidal, LSA: lagoon surface area, MD: mean water depth, WSA: watershed surface area, MAL: main economical activities in the lagoon, MAW: main economical activities in the watershed

Lagoon	Country	Geographic coordinates	TR	SAL km^2	MD m	WSA km^2	MAL	MAW
Ria Formosa	Portugal	36°58'-37°10'N 08°06'-07°37'W	M	106	3.5	864	Clam harvesting	Urbanisation Tourism
Mar Menor de Murcia	Spain	37°38'-37°49'N 00°53'-00°44'W	m	135	4.0	1200	Tourism	Agriculture Urbanisation
Etang de Thau	France	43°20'-43°28'N 03°32'-03°42'E	m/n	75	4.5	280	Oyster-Mussel farming (high)	Agriculture Urbanisation
Sacca di Goro	Italy	44°47'-44°50' N 12°15'-12°20' E	m	26	1.5	860	Clam farming (high)	Agriculture
Gulf of Gera	Greece	39°00'-39°07'N 26°27'-26°32E	m/n	43	10.0	230	Fish cage farming (low)	Agriculture

Notten *et al*. (2003). Our scenarios are normative rather than descriptive as they draw

Figure 1. Map of the Southern Mediterranean Arc with the location of sites considered in the DITTY project.

probable or preferable futures and not only possible futures. This is especially true since we screen various management options in order to attain a "good ecological status" for lagoons, as indicated in the WFD. They are forecasting as we take the present as a starting point. They will be, in a second step, put into a DSS which will, according to economical and environmental criteria, help in ordering the results using multicriteria analysis and hierarchical classification. In any case, they are not meant to provide future predictions with an associated probability, but they aim rather to support policy and decision makers in their efforts to cope with future uncertainties.

In the context of DITTY the general objective is to combine an Integrated River Basin Management (IRBM) with an Integrated Coastal Zone Management (ICZM) as targeted in the WFD, in order to prevent and mitigate possible adverse conditions induced in the coastal lagoon by the development of human activities in the watershed, but also to assure a sustainable development of the socio-economic activities within the coastal lagoon. In this context, it is necessary to evaluate which amount of human impact the coastal lagoon may tolerate and what is the admissible margin for maintaining conditions–corridors of sustainability (Ledoux and Turner, 2002). Both those questions, have to be answered taking into account that non linear cause-effect relationships link the pressures, e.g. nutrient loads, with the state of the ecosystem as well as considering the existence of thresholds, points of non-return and hysteresis effects (de Wit *et al*., 2001; Muradian, 2001; Scheffer *et al*., 2001).

To set-up a general framework for scenarios definition, we adopted the scenario scheme which was developed in the EUROCAT (European catchments changes and their impact on the coast, EVK1-CT-2000-00044) Project. Three general scenarios have been defined and used in the five study sites when appropriate, in order to cope with environmental and economical issues.

The Business As Usual (BAU) scenario is based on the assumption of the continuation of current trends in the future. In this case prevailing trends will be allowed to continue without major intervention.

The Policy Targets (PT) scenario is based on the assumption that in the future all current regulatory standards and targets will be met. This is equivalent to the implementation of the Water Framework Directive with all its requirements.

The Deep Green (DG) scenario is based on the assumption that there is a shift in EU society towards environmental conservation goals in preference to economic growth-related objectives. In this case, the goal will be the re-establishment of “pristine” conditions subject to the historical legacies.

The DPSIR framework

The DPSIR (Drivers-Pressure-State-Impact-Response) framework has been adopted within the DITTY project to facilitate the integration of scientific issues with needs of end-users and stakeholders. The DPSIR has been also used to define the modelling input-outputs, necessary to take into account the different priorities selected by end-users and stakeholders for each lagoon. DPSIR was first developed for environmental reporting by the OECD (1993) and it was further developed and adapted to the context of coastal management by Turner *et al*. (1998). This scheme uses indicators to represent the elements of the chain, thus simplifying the information which is conveyed to broad groups of stakeholders and the general public in short, clear messages, thus enhancing the transparency of decision-making (OECD, 2002). This standard framework has been largely used in applying the WFD and assessing the impact of pollution in transitional waters (Borja *et al*., 2006; Newton *et al*., 2004).

Figure 2 illustrates the DPSIR applied to the DITTY test sites. At the root of environmental change are economic drivers, e.g. intensification of agriculture, shellfish farming and industrial activities, urbanisation and tourism development. In turn, drivers will generate pressures, e.g. land conversion and reclamation, nutrient emissions, waste disposal, dredging, etc. These pressures, along with other factors such as climate change, will alter the state of the environment. For example, changes in nutrient concentration will lead to increased risks of eutrophication and, subsequently, oxygen deficit and anoxia will cause loss of habitats and species diversity. Such environmental changes will in turn have an impact on human activities and welfare, for example through losses of aquaculture productivity or health impacts on coastal populations. The effects of these impacts have to be measured using environmental economics instruments in terms of costs and benefits to society. Furthermore, suitable measures should be taken in order to manage for reducing pressures, to ameliorate the environmental state and hence to reduce impacts on human populations and activities.

Predicting how future socio-economic changes in the watersheds and coastal lagoons might affect water quality, requires in the first place the ability to describe the present state of the whole system (watershed and lagoon), and the impacts of past and current socio-economic drivers and pressures on water quality and aquatic ecosystem features. Such work has been developed in the early phase of the project, when the existing knowledge for each lagoon was analysed and synthesized (see for example Viaroli *et al.*, 2006). Once the link between drivers, pressures and impacts is understood, policy responses may be formulated to reduce the pressures created by certain drivers and the impacts of certain pressures on water quality and ecosystem structure. However, policy implementations will certainly have wider implications that have to be assessed using future scenarios.

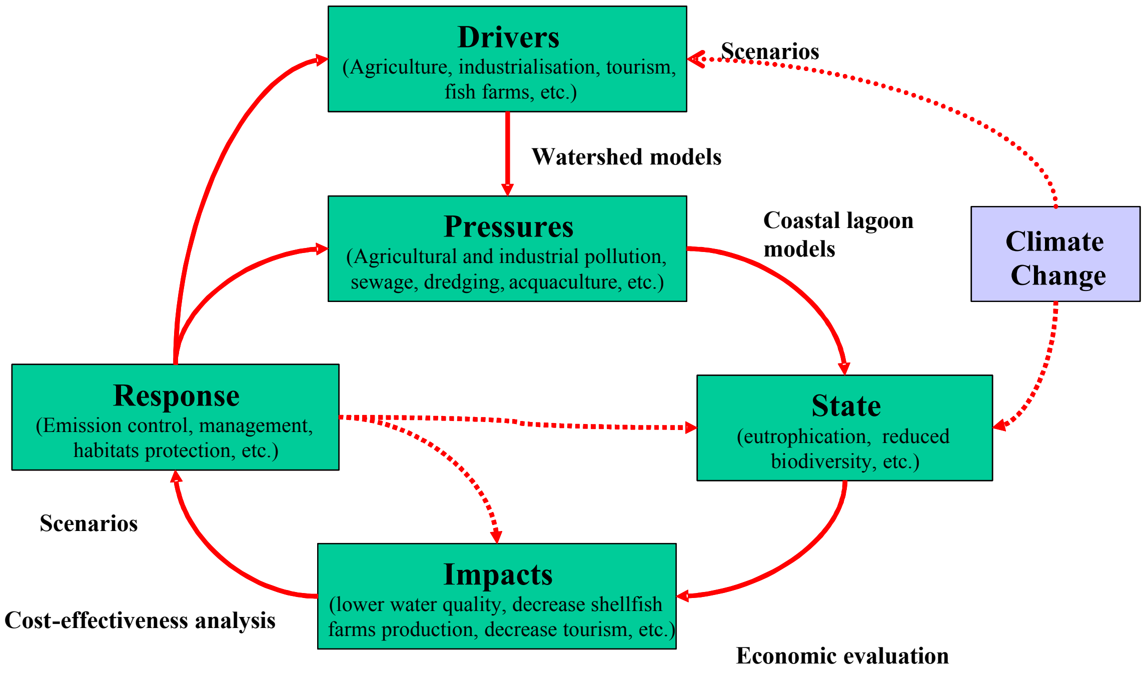

Figure 2. DPSIR scheme implemented in the various DITTY sites.

Modelling tools

In table 2 the general components of the DPSIR approach to watershed and lagoons for all DITTY test sites are presented. Connection to lagoon modelling is only in terms of outputs from the watershed treated as forcing functions (water flows, sediment, nutrient and bacteria concentrations). Scenario analysis was performed following two different approaches: (i) run the watershed model for each scenario; or (ii) assign reduction coefficients related to each pressure to estimate changes in impact. For example, in the case of nutrient loads, we assume that each hectare of cropland contributes a certain amount of nitrogen to the lagoon, and the nitrogen load varies proportionally with the crop surface. The watershed influence on the lagoon may be evaluated in terms of freshwater flow, bacteria, nutrient and sediment loads. Such loads will depend on land use, fertilization practice, waste-water treatment level and weather conditions. The models used to simulate the watershed outputs were SWAT-MODFLOW for Sacca di Goro and SWAT for Thau lagoon. The same scenarios adopted for the watersheds were studied for the lagoon environments. As already said earlier, connection to watershed modelling is only in terms of outputs from the watershed treated as forcing functions. Lagoon models applied within the DITTY project were COHERENS for Sacca di Goro (Marinov *et al.*, 2006), MARS3D for Thau (Lazure, 1992), and EcoDyn for Ria Formosa (Duarte *et al.*, 2006). Hydrodynamic models were coupled with biogeochemical models to account for the various physical and biological processes taking place in the lagoon. Models were then adapted and biological modules added to fit the scenario requirements. For example the 3D hydrodynamic-biogeochemical model developed both for water column and sediments of the Sacca di Goro lagoon includes nutrients, phytoplankton, zooplankton, bacteria and *Ulva* dynamics, as well as shellfish farming (Zaldivar *et al*., 2003). Due to the legislative framework of all the DITTY test sites, it has been decided to define a timing for the analysis of future scenarios from the present status to 2015, which is the deadline foreseen in the WFD for achieving of "good ecological status", or "good ecological potential" in the case of heavily modified water bodies. So the scenarios developed in this study have a short-term temporal dimension. The scenarios were run at the watershed and coastal lagoon scales, which is dictated not only by data availability, socioeconomics and modelling needs, but also by the spatial scale of management and planning. The latter basically depending on rules of public administrations and needs of end-users, which have mainly a local to regional dimension.

Scenarios quantification and evaluation

Scenario analysis was developed by expanding studies from a descriptive approach to a quantitative assessment. Each of the scenarios was developed assuming the year 2015 as time horizon. Given the short-time frame, climate change was not taken into account as a separate driver, but rather it was built-in in each scenario by introducing appropriate variations to weather time series for each site. Quantification of parameter variation for each scenario was performed using different tools which are described in the papers of this monograph issue.

Effects of nutrient loads

The nutrient loads delivered from the watershed to the receiving coastal lagoon is usually driven by changes in agricultural practices or population growth. The nutrient increase stimulates primary productivity in the lagoon, which often leads to an accumulation of organic matter.

In ecosystems dominated by phytoplankton, a large amount of the primary production bulk can be processed by filter-feeders with an increase of the secondary productivity. For this reason a number of coastal lagoons are exploited with mollusc farming (Officer *et al*., 1982). In the latest stages of eutrophication processes, the community often become dominated by ephemeral blooming macroalgae, such as *Ulva*, and the biomass bulk is not grazed but accumulates within the lagoon (Schramm, 1999). The macroalgal biomass is then decomposed with a high oxygen demand which encompasses the oxygen production, leading to the predominance of anaerobic processes and dystrophic crisis (Castel *et al*. 1996; Viaroli *et al*., 2001, 2006). Deviations from these patterns can be seen in lagoon, such as the Mar Menor of Murcia (South of Spain), where eutrophication processes alter the community structure with an abnormal growth of jellyfish and the displacement of other invertebrates and fish species. Overall, these changes have a cascade effect on several bird assemblages. The summer jellyfish blooms can also deteriorate the bathing quality which in turn affects tourism and causes economic losses (Martinez *et al*., this volume). In the studies performed in the DITTY project, the catchment model was used to predict the outcomes of changing loads and quality status for nutrients, either on a daily or annual scale. The output was then used to feed a lagoon model which included both phytoplankton and macroalgae or seagrass compartments, to estimate at which level of nutrient fluxes the dominance in primary producer communities can be changed, and to simulate the consequences of these structural changes both on exploited productivity and biogeochemical equilibria. A joint analysis by modellers and social scientists investigated the effectiveness and the feasibility of different measures (e.g. improved sewage treatment, change in agricultural practice) for decreasing loads and improving water quality. Finally, cost-benefit analysis has allowed the identification of the most cost-effective options to reach nutrient reduction targets within the analyzed scenarios.

Table 2. Relevant lagoon driving forces and impacts. (*) Level depends on scenario's targets

Driver	Pressure	State	Impact	Policy response (*)
Agriculture	Increase in farmed land and livestock: fertilizer and pesticide use freshwater consumption for irrigation manure application on land and wastewater delivery from livestock reclamation of wetlands and marginal lands	Changes in salinity Changes in nutrient concentrations Development of bacteria of sanitary concern Contamination by pesticides Changes in community structure	Altered freshwater/saline water equilibrium Reduced water quality Damage to aquatic ecosystem Eutrophication: Macroalgal blooms Harmful algal blooms (HABs) Anoxic crises	Decrease farmland area Decrease livestock Adopt BMP to decrease diffuse source load Increase treatment level for farm wastewater Designate watershed as Nitrate Vulnerable Zone (NVZ)
Aquaculture	Increase in fish and shellfish farm area: introduction of farmed species trawling, sediment dredging	Changes in community structure Changes in sediment features and composition Chanes in biogeochemical processes	Reduced water quality Hypoxic/anoxic conditions Introduction of exotic species Habitat destruction Biodiversity loss	Limits/restriction to fish and shellfish farm concessions Adopt BMP to decrease ecosystem alterations
Industry	Increase in number and magnitude of industrial establishments: freshwater consumption for processing/cooling pollutant emission soil impermeabilisation	Changes in salinity Eutrophication Contamination by POP and heavy metals Changes in sediment and composition and biogeochemistry	Altered freshwater/saline water equilibrium Reduced water quality Damage to aquatic biota due to toxic contaminants	Decrease industrial density Increase treatment level for industrial wastewater Increase wastewater reuse Develop buffer zones
Urban and tourism development	Increase in resident and seasonal population: wastewater production freshwater consumption wetland reclamation soil impermeabilisation	Eutrophication Development of bacteria of sanitary concern Contamination by POP	Altered freshwater/saline water equilibrium Reduced water quality Eutrophication Anoxic crises	Increase treatment level for domestic wastewater Increase wastewater reuse Develop buffer zones
Climate change	Temperature increase and changes in rainfall patterns (increased frequency of high intensity rainfall events, increased number and duration of dry periods): Freshwater consumption in all sectors Changes in runoff and sediment transport Sea level rise	Changes in oxygen solubility and budgets Changes in nutrient budgets Changes in suspended particulate matter Changes in water budgets due to extreme single-event (drought/flood)	Altered freshwater/saline water equilibrium Sediment erosion and loss of habitats Threats to biodiversity Alteration of biological cyles Biological invasion	Increase the level of land protection measure Riverbed and stream slope correction

Effects of bacteria of sanitary concern

Bacteria of sanitary concern originate mostly from domestic and animal farming sewage. Domestic wastewater is to a large extent treated through appropriate plants. However, accidental contamination during wastewater plant failure or flooding event may occur threatening cultivated stocks and/or recreational activities inside the lagoon. The growing population inhabiting permanently or seasonally the basin of the coastal lagoons adds further concern on the sanitary quality of water inside the lagoon. A management option is to improve the water treatment network by creating new plants or by increasing the level of treatment (e.g. chlorination, UV, ozone, filtration) of existing systems. During the last twenty years, a large knowledge has been developed on the behaviour of enteric micro-organisms which can reach coastal ecosystems (Troussellier *et al*., 1998) where they may cause contamination of recreative waters and shellfish farms (Prieur *et al*., 1990). Knowledge on adaptative responses of enterobacteria to marine environmental stresses has lead to the development of mathematical models (Martin *et al*. 1998), which can be used as a support to simulate the distribution and fate of bacterial contamination when coupled with hydrodynamical models.

For Thau lagoon this is the principal scenario explored, since bacterial contamination reached, in the past few years, threatening levels both in the water column and in the cultured mollusc. As a consequence, and to minimize sanitary risks for citizens, the lagoon was downgraded from A to B sanitary quality class in June 2004 according to the EU Directive (Loubersac *et al*., this volume).

Changes in resource exploitation

The problem to be addressed here is specific for each lagoon. In Sacca di Goro for example, more than one third of the lagoon surface is exploited for clam farming, producing in the early 1990s a maximum of 15 000 t y $^{-1}$ with an economic revenue from 30 to 50 million Euros. In 2004 private companies and cooperatives submitted a request for increasing the exploited area of about 30%. An assessment of the potential risk/impact derived from the enlargement of the farmed area was made considering the oxygen consumption, nutrient cycles and farms locations (Viaroli *et al*, this volume). This scenario has been studied using a quantitative approach based on a 3D integrated biogeochemical model. Furthermore, nutrient reduction options as well as climatic variability have also been taken into account to examine simultaneously the combined effects and the complex interactions between several stressors.

Effects of Climate Change

As mentioned before, no climate change scenario was actually evaluated as a separate test case along with BAU, PT and DG scenarios. Rather, from a common climate change scenario keeping into account long term climate variation, synthetic series for weather data were generated at various sites for the time frame indicated in the WFD (2015).

Other scenarios

Desalination and re-use of agricultural drainage in irrigation and optimisation of wetlands associated to the lagoon shore for nutrients removal were explored in combination of the latter two scenarios in Mar Menor (Martinez *et al*., this volume).

Scenarios on dredging operation and water circulation changes were considered in Ria Formosa. These scenarios reproduce changes in lagoon bathymetry and/or inlet width resulting from hypothetical dredging and sediment accretion operations within some areas. This is to simulate a current practice among bivalve producers of adding sand to their rearing areas, in order to improve sediment quality for bivalve growth (Duarte *et al*., this volume).

The scenario analysis in the Gulf of Gera allowed an assessment of threats in a relatively uncontaminated site, where the development of aquaculture, agriculture and tourism underwent slight changes only in the last few years (Kontogianni *et al*., this volume).

Even though our study system is well-defined, i.e. Southern European coastal lagoons, with similar ecological problems, i.e. water quality– nutrients, contaminants, bacteria of sanitary concern, anoxic crises, algal blooms; each test site has placed different emphasis and priorities regarding the beforehand mentioned problems.

This is the consequence of very different local economies. Therefore, the scenarios developed in DITTY are site specific and provide a large spectrum of various contexts, which are provided in the following papers for each site. The various scenarios and their most important impacts in terms of ecological and economical issues are then developed giving a broad representation of ecosystem state and possible threats which can be applied overall in the Southern European Arc region.

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